Particle Size Distribution (PSD) Working Group Update

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PSD WG Co-Chairs:

Stephen Nesbitt

University of Illinois at Urbana-Champaign

S. Joe Munchak

University of Maryland, College Park

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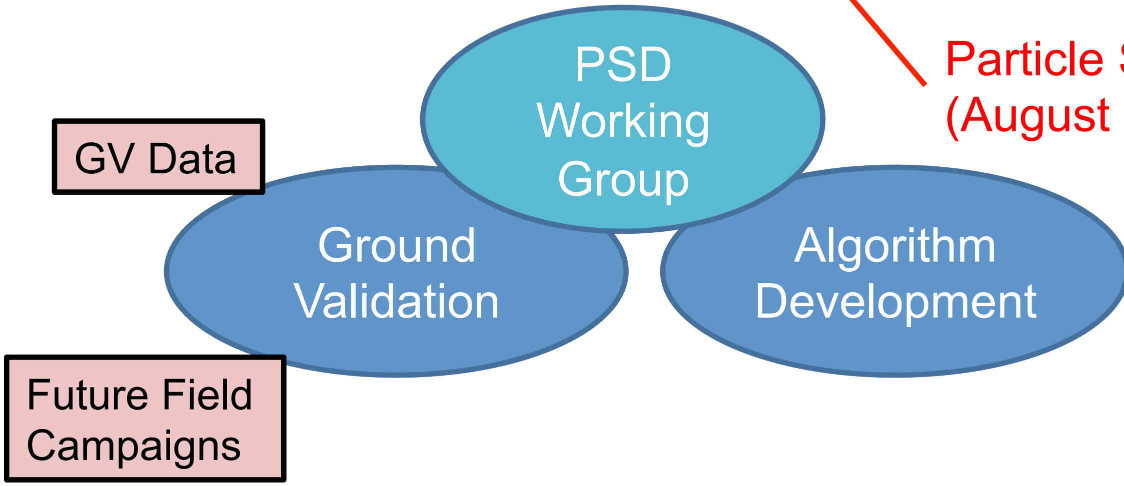
NASA PMM ~~DSD~~ Working Group: Bridging Ground Validation (GV) and Algorithms

Particle Size Distribution (PSD)
(August 2014)



PSD WG General Objective: Use Ground Validation (GV) data to support, or justify, assumptions used in satellite retrieval algorithms.

Today's Outline:
1) Accomplishments of DSD Working Group
2) Describe 5 PSD sub-groups & their focus to improve retrieval algorithms
3) Highlight activities in Non-Uniform Beam Filling (NUBF) sub-group

PSD Working Group Monthly phone calls: 3rd Thursday @ 11 AM Eastern (US).

Simplified Equations

$N(D) \sim A\, f(D)$ drop distribution

$m(D) \sim B\, f(D^3)$ mass distribution

$z(D) \sim C\, f(D^6)$ reflectivity distribution

Scalar

N_w, N_0^*, N_t

mean & breadth

D_m, D_0 σ_m, μ

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Scalar

N_w, N_0^*, N_t

mean & breadth

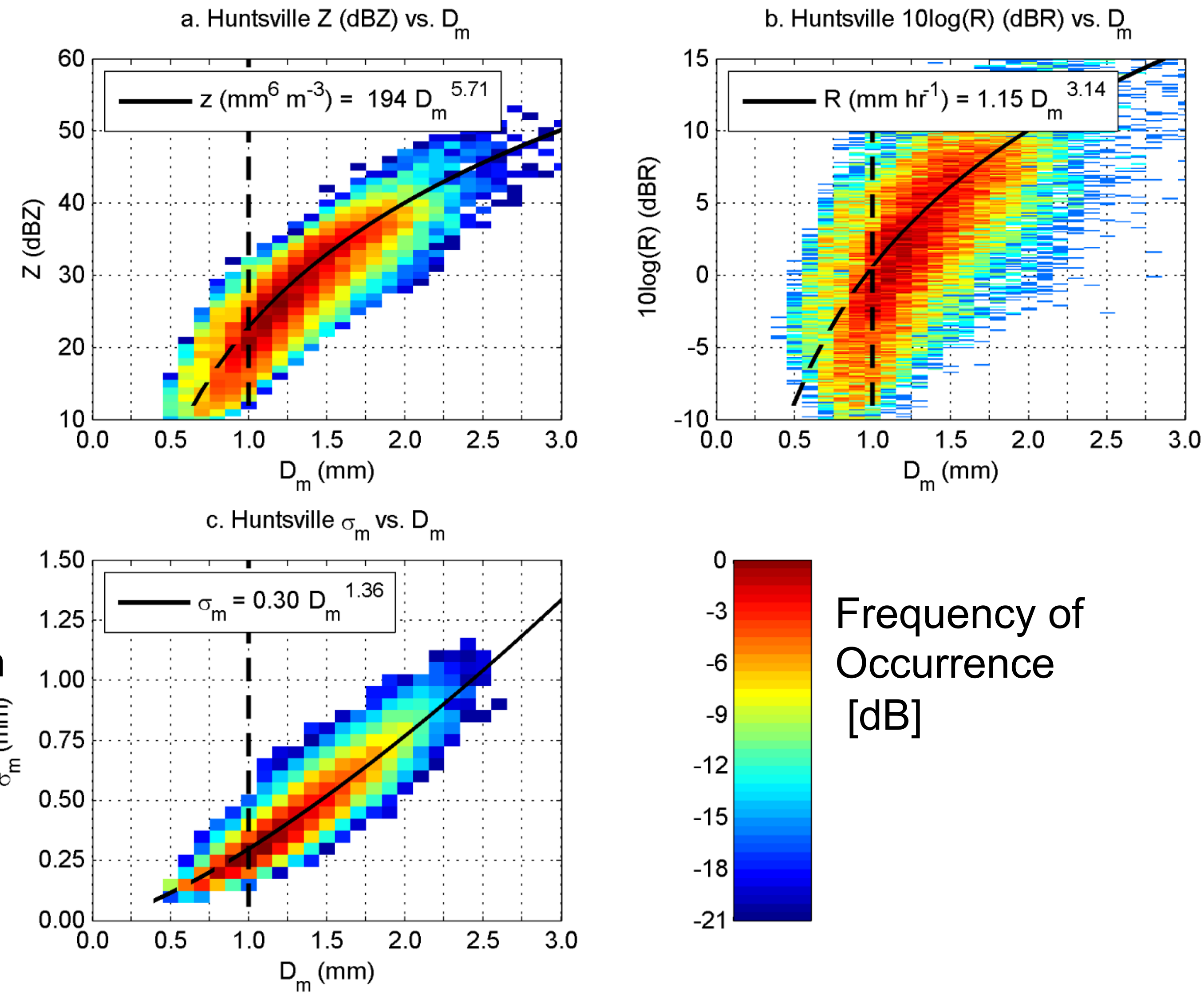
D_m, D_0 σ_m, μ

$$z\left[\mathrm{mm}^6/\mathrm{m}^3\right] = N_w \sum f\left(D^6; D_m, \sigma_m\right)$$

$$Z\,[\mathrm{dBZ}] = 10\log\left(N_w\right) + 10\log\left[\sum f\left(D^6; D_m, \sigma_m\right)\right]$$

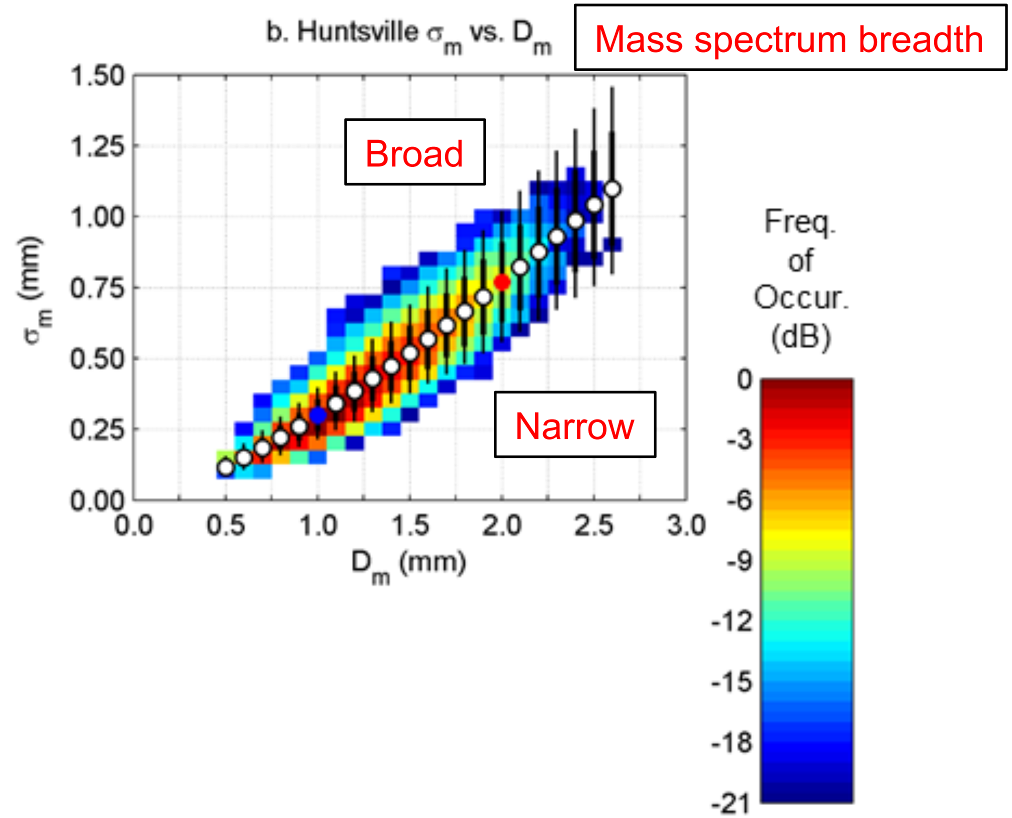
$$Z\,[\mathrm{dBZ}] = 10\log\left(N_w\right) + I_b\left(D_m, \sigma_m\right)$$

Disdrometer Moments: Huntsville

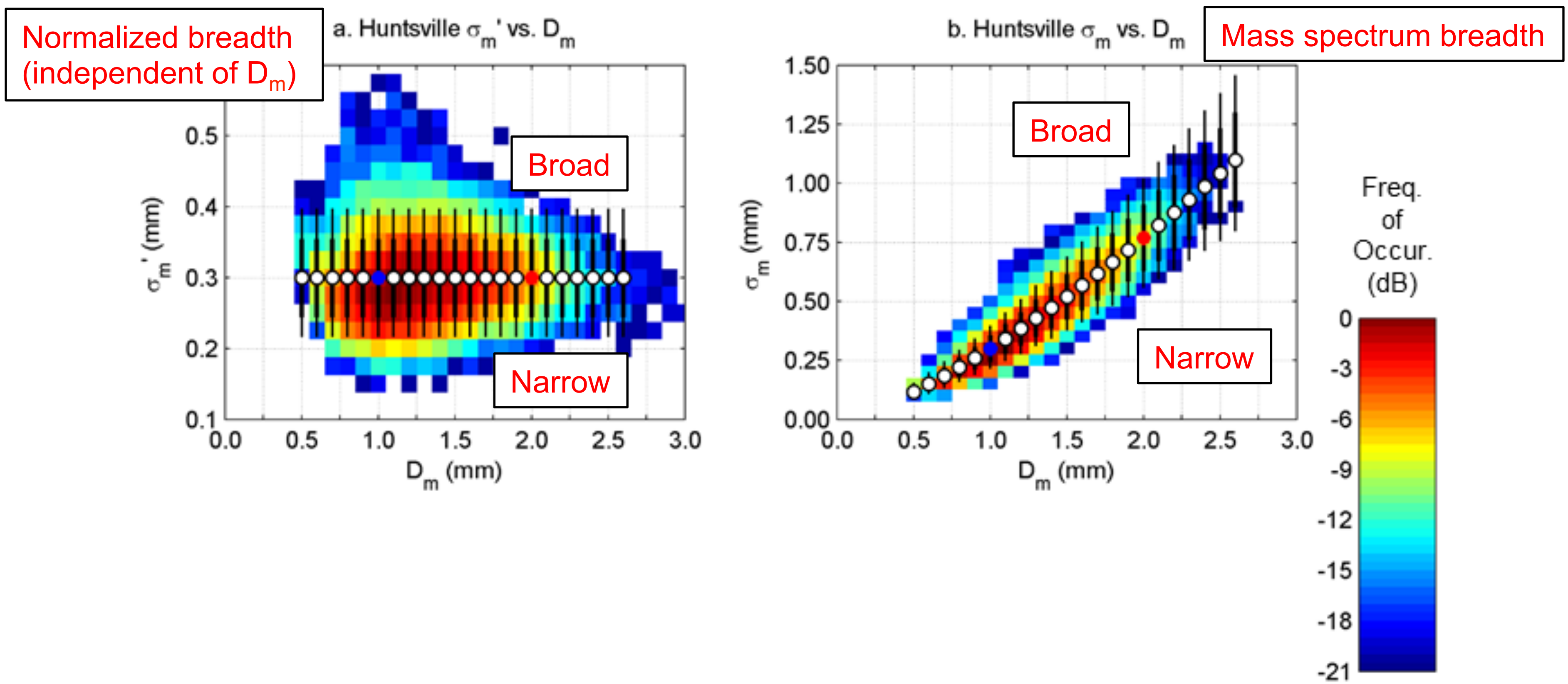


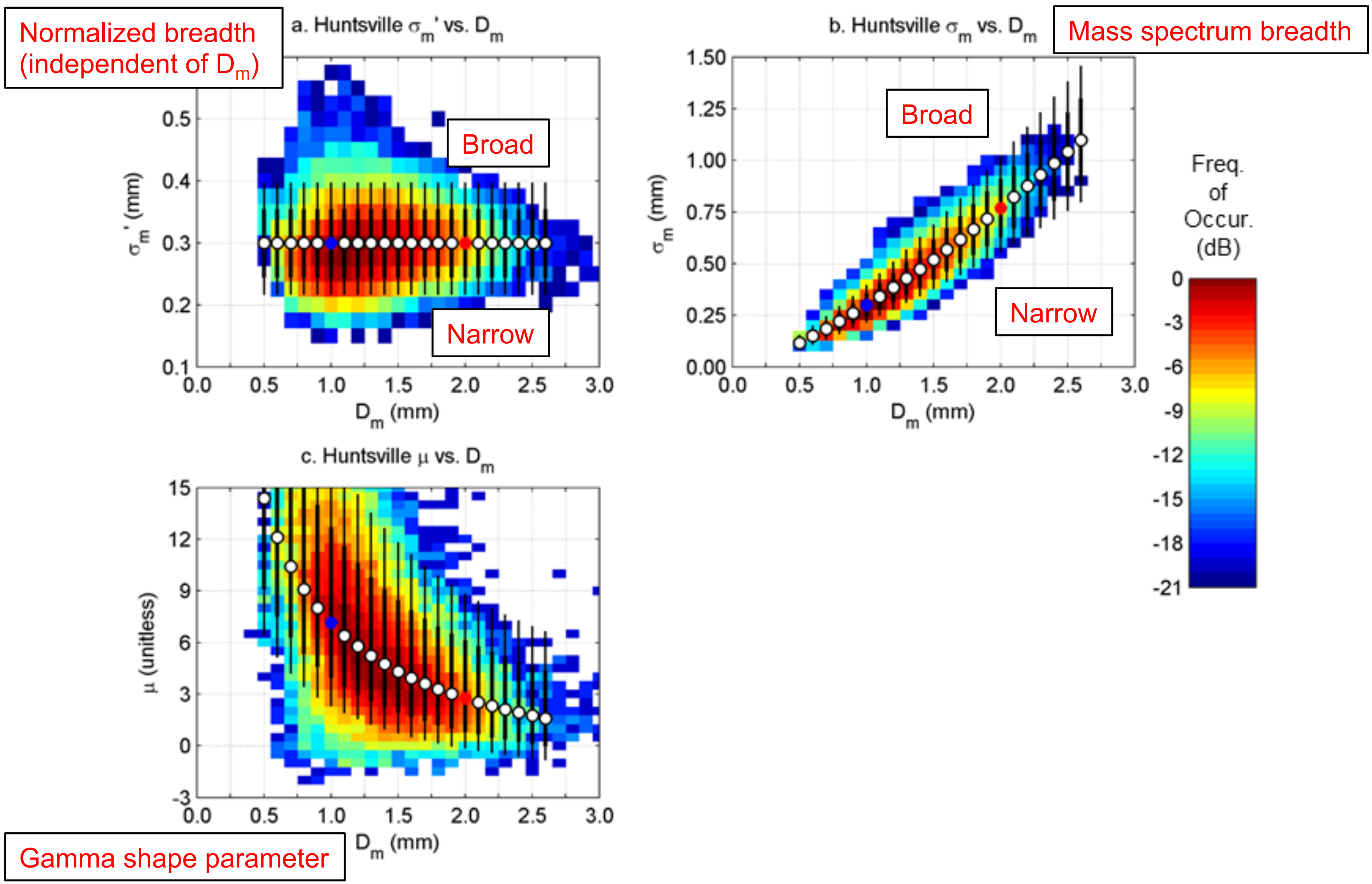
Mass distribution breadth

Mass distribution mean



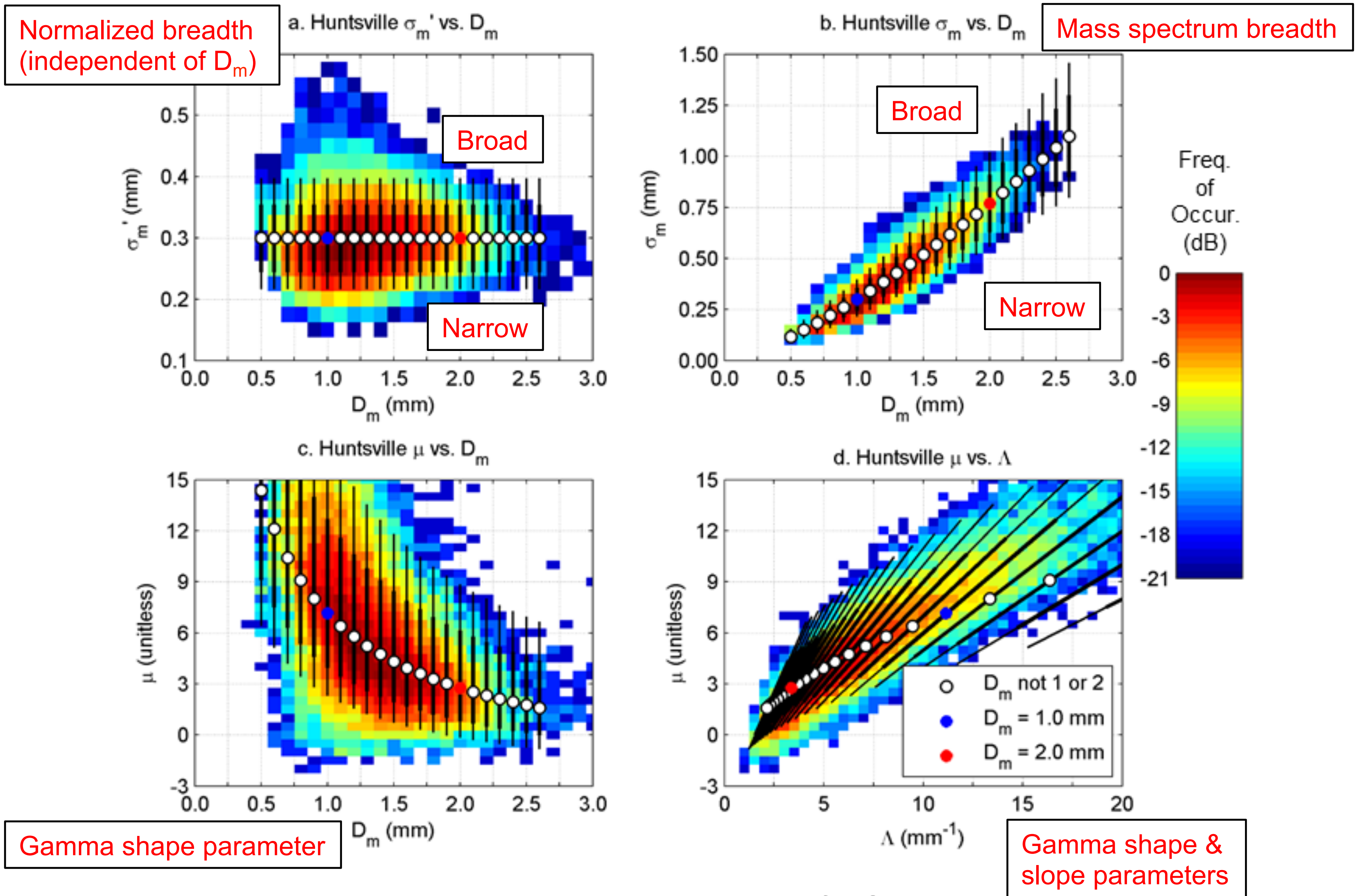
b. Huntsville σ_m vs. D_m
Mass spectrum breadth
Broad
Narrow
σ_m (mm)
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
3.0
D_m (mm)
Freq. of Occur. (dB)
0
-3
-6
-9
-12
-15
-18
-21


Normalized breadth (independent of D_m)
a. Huntsville σ_m' vs. D_m
Broad
Narrow
σ_m' (mm)
D_m (mm)
b. Huntsville σ_m vs. D_m
Mass spectrum breadth
Broad
Narrow
σ_m (mm)
D_m (mm)
Freq. of Occur. (dB)



Joint PDFs provide expected value and range of DSD parameters for probabilistic retrieval algorithms.

(Williams et al. 2014, 2015)



Joint PDFs provide expected value and range of DSD parameters for probabilistic retrieval algorithms.

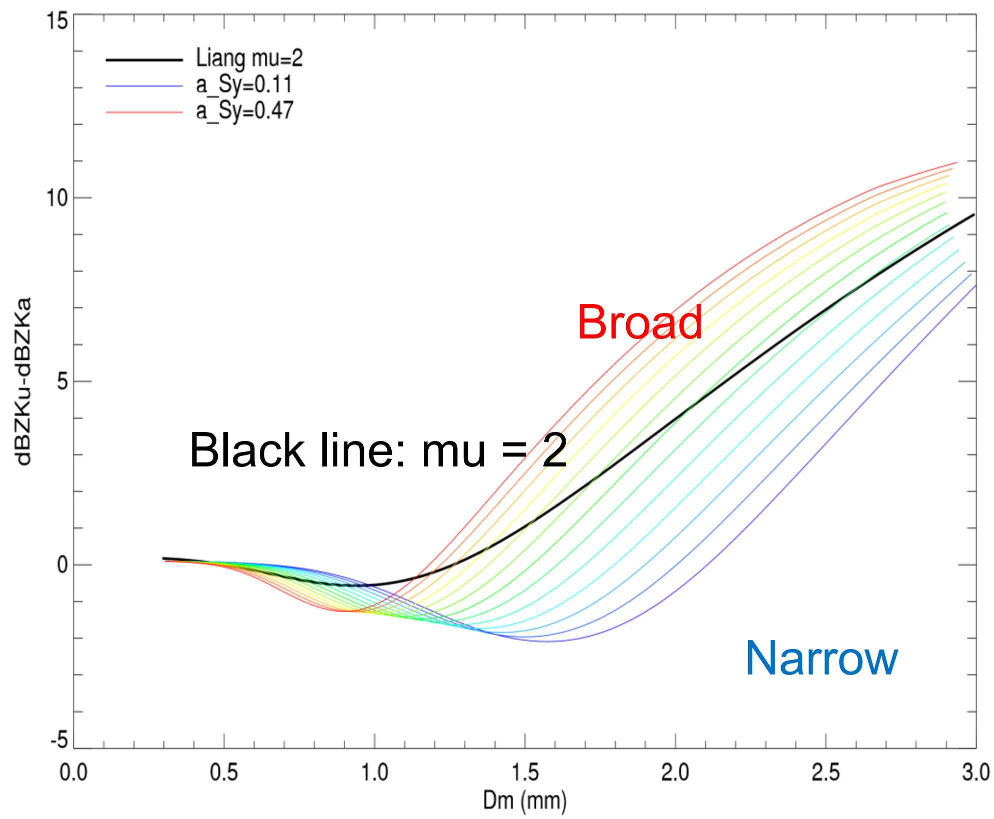
(Williams et al. 2014, 2015)

Radar Integral Tables

Use mass spectrum standard deviation (sigma_m) to describe DSD breath. (Physical quantity)

LUTs using sigma_m have been evaluated in the Combined Algorithm and may be used in V04

DFR = Dual Frequency Reflectivity Ratio

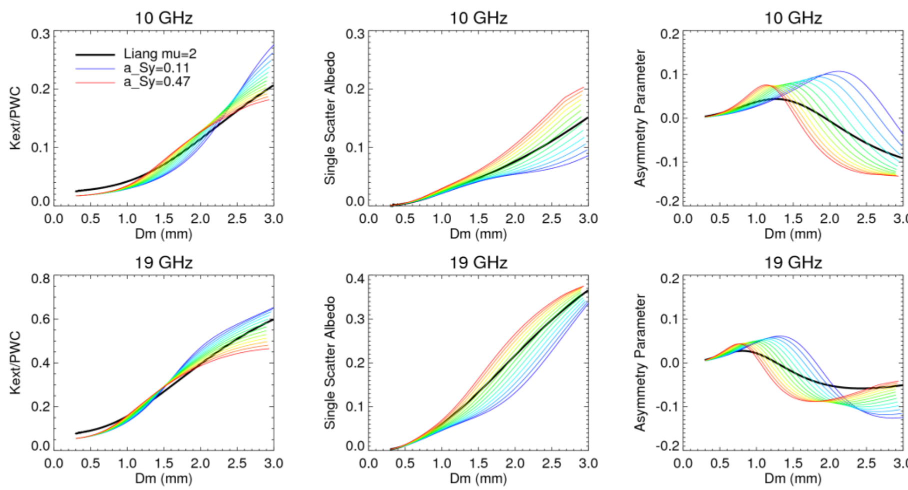


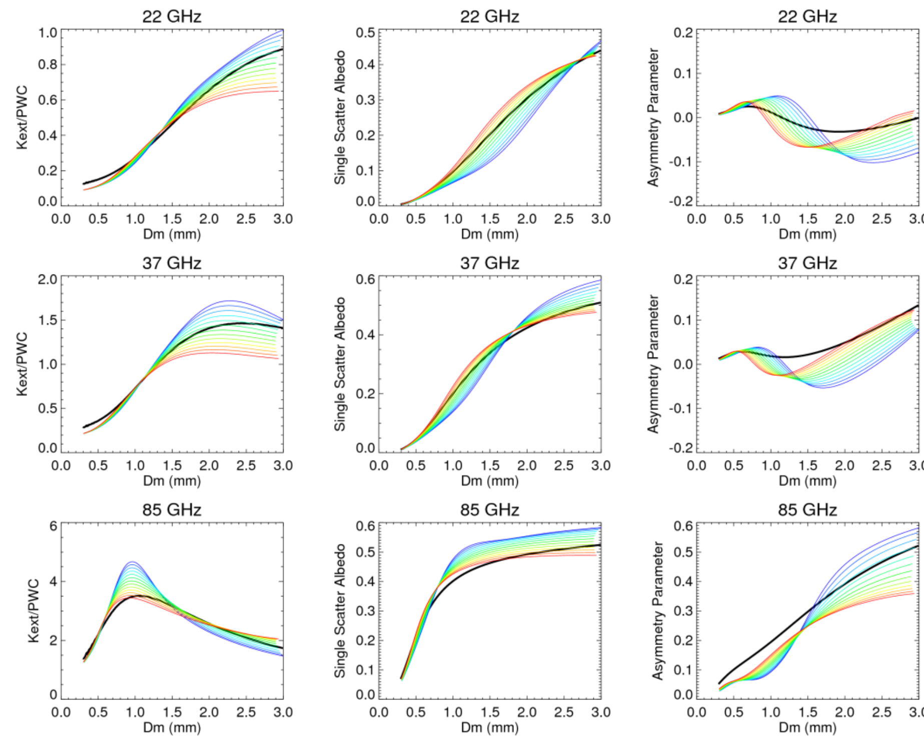
From Joe Munchak

Radiometer Integral Tables

Use mass spectrum standard deviation (sigma_m) to describe DSD breath. (Physical quantity)

LUTs using sigma_m have been evaluated in the Combined Algorithm and may be used in V04





Narrow (a_{σ_y} = 0.11) Broad (a_{σ_y} = 0.47)

Improved Working Group Focus & Leadership

- 25 members & 30 associate members
- To include solid precipitation, changed Working Group name to:
  - Particle Size Distribution (PSD) Working Group
- Improved Leadership:
  - **Christopher Williams** – (lead-chair) DSD parameter relationships and column observations
  - **Steve Nesbitt** – (co-chair) building the column and incorporating aircraft observations
  - **Joe Munchak** – (co-chair) algorithm prospective and issues with ice & frozen PSDs

PSD Sub-Groups (Defined August 2014)

Themes for NASA PMM PSD Working Group

- *Light Rain Estimation* – Chandra
- *Melting Layer Characteristics* – Ben Johnson
- *Non-Uniform Beam Filling (NUBF)* – Walt Petersen
  - *PIA(Ka) / PIA(Ku) Relationship* – Christopher Williams
- *Solid Precipitation* – Steve Nesbitt
- *DSD / PSD Parameter Relationships* – Brenda Dolan

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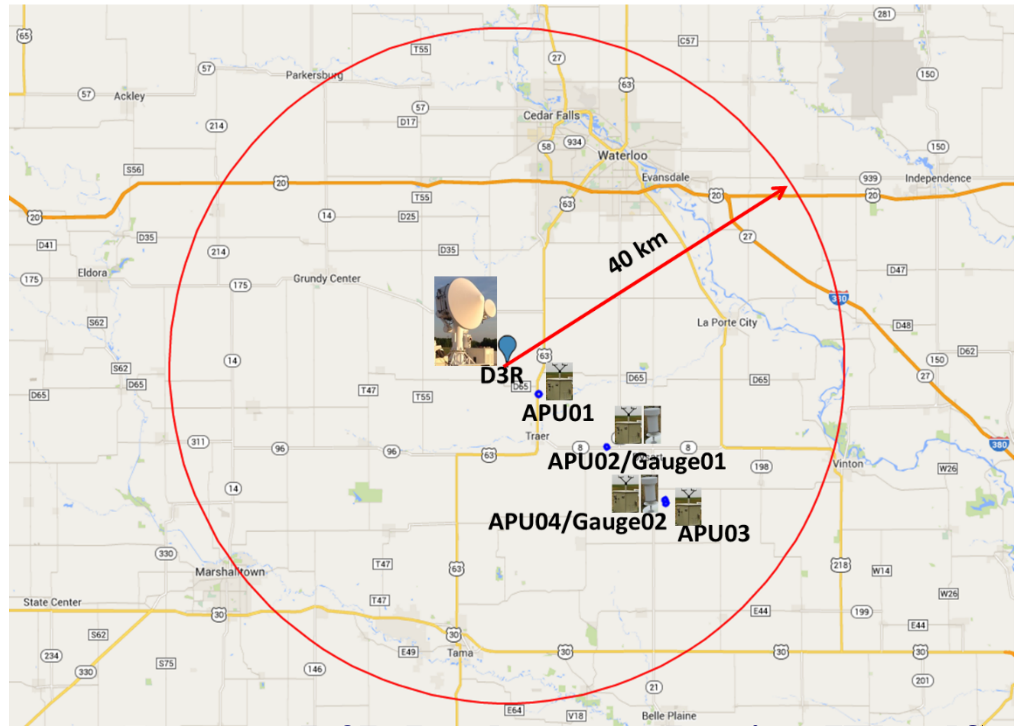
Deployment during IFloodS

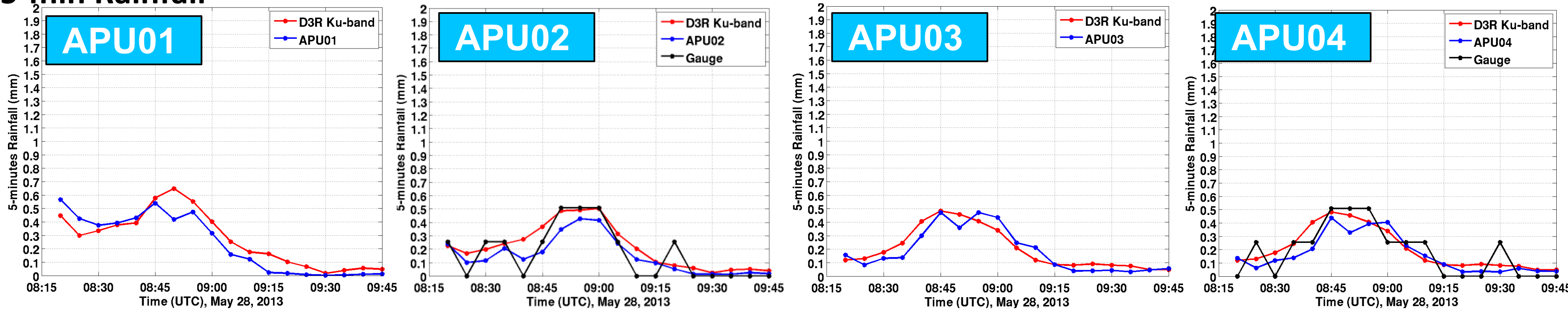
Iowa Flood Studies (IFloodS): a ground measurement campaign to collect detailed measurements of precipitation at the Earth's surface using ground instruments and advanced weather radars and, simultaneously, collect data from satellites passing overhead (May 1 to June 15, 2013).



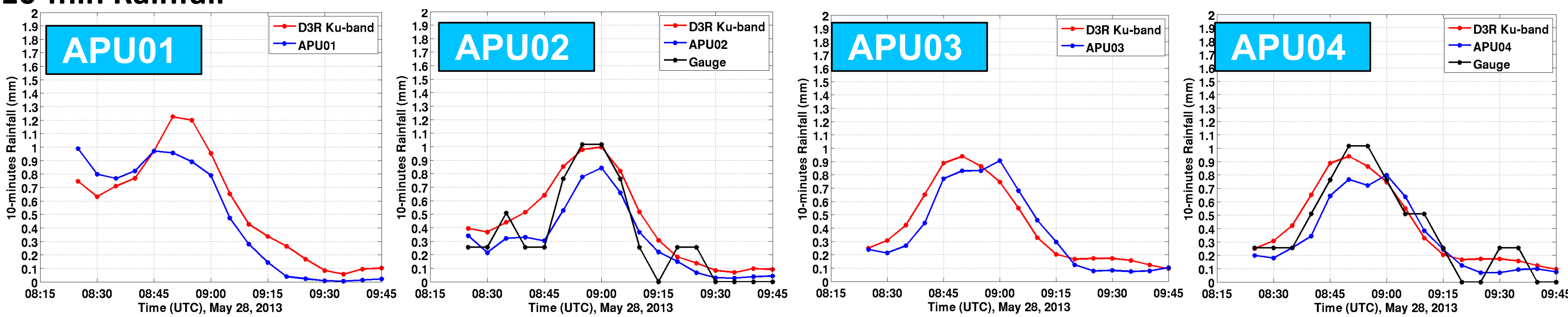
D3R Deployment During IFloodS

Sample Light Rain Products: 28 May 2013

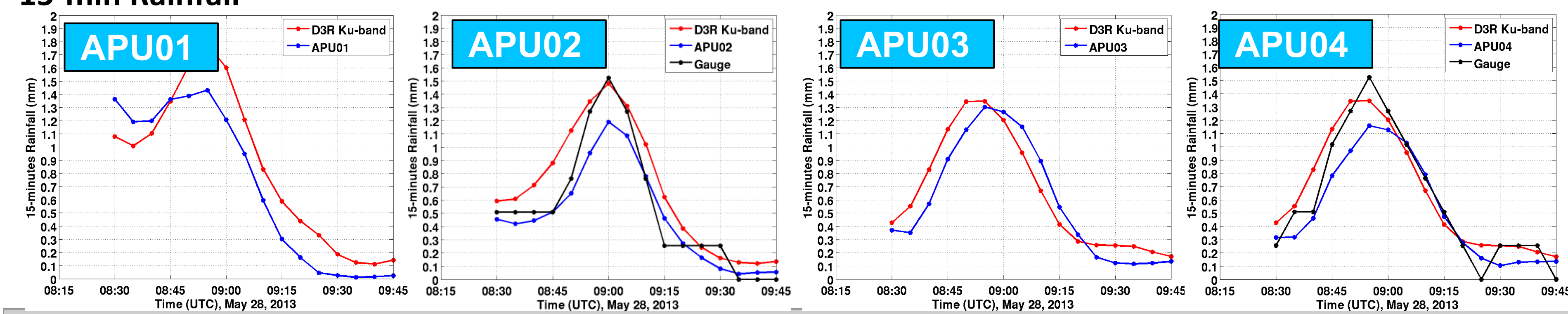
5-min Rainfall



10-min Rainfall



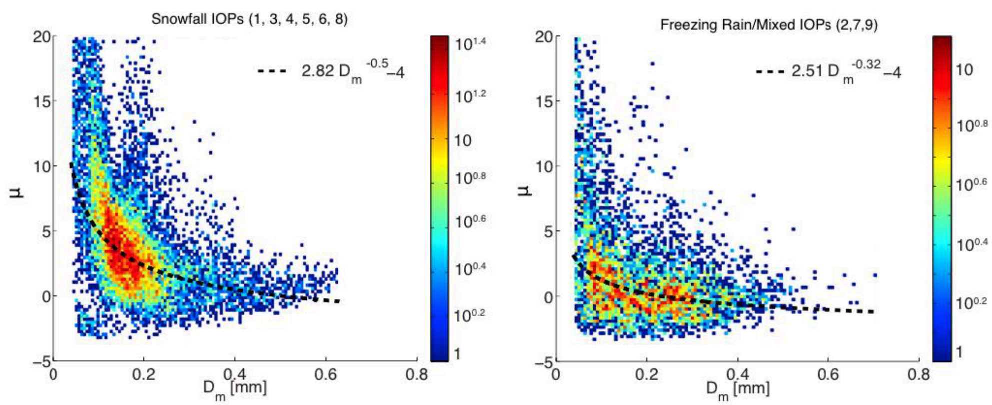
15-min Rainfall



GV algorithm issues in cold-season precipitation – Solid PSD Sub-Working Group

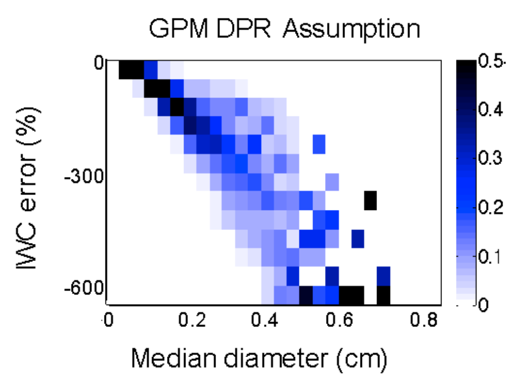
- Particle size distribution constraints in snow following Williams et al. 2014 (K. Harnos et al. 2015)
- Scattering properties in natural ice, mixed-phase particles (S. Tanelli)
- Particle mass/density – Ice water content (IWC) – retrievals (A. Heymsfield, S. Tanelli, U. Illinois)
- Fall speeds (U. Illinois, A. Tokay)
- Mixed-phase processes, supercooled water, and riming (B. Johnson, U. Illinois)

GCPEx data analysis of σ_m – D_m – μ framework



Probabilistic PSD framework separates for "dry snow" versus "mixed phase" events

Examining impacts of mass-diameter relationships on retrievals:



Vertical DSD/PSD Subgroup: Motivation

- DFR is independent of Nw and constrains other two DSD parameters (Dm and sigma_m)
  - Not simple retrieval due to radar noise, cloud water and water vapor attenuation, errors propagate and accumulate
- To mitigate noise, need *vertical constraint* on DSD variability
  - Prescribe a vertical covariance structure on a DSD parameter

    -OR-
  - Only retrieve DSD parameters at certain ‘nodes’ (similar to single-frequency algorithm)
- Ice PSDs: how can we construct DSD tables?

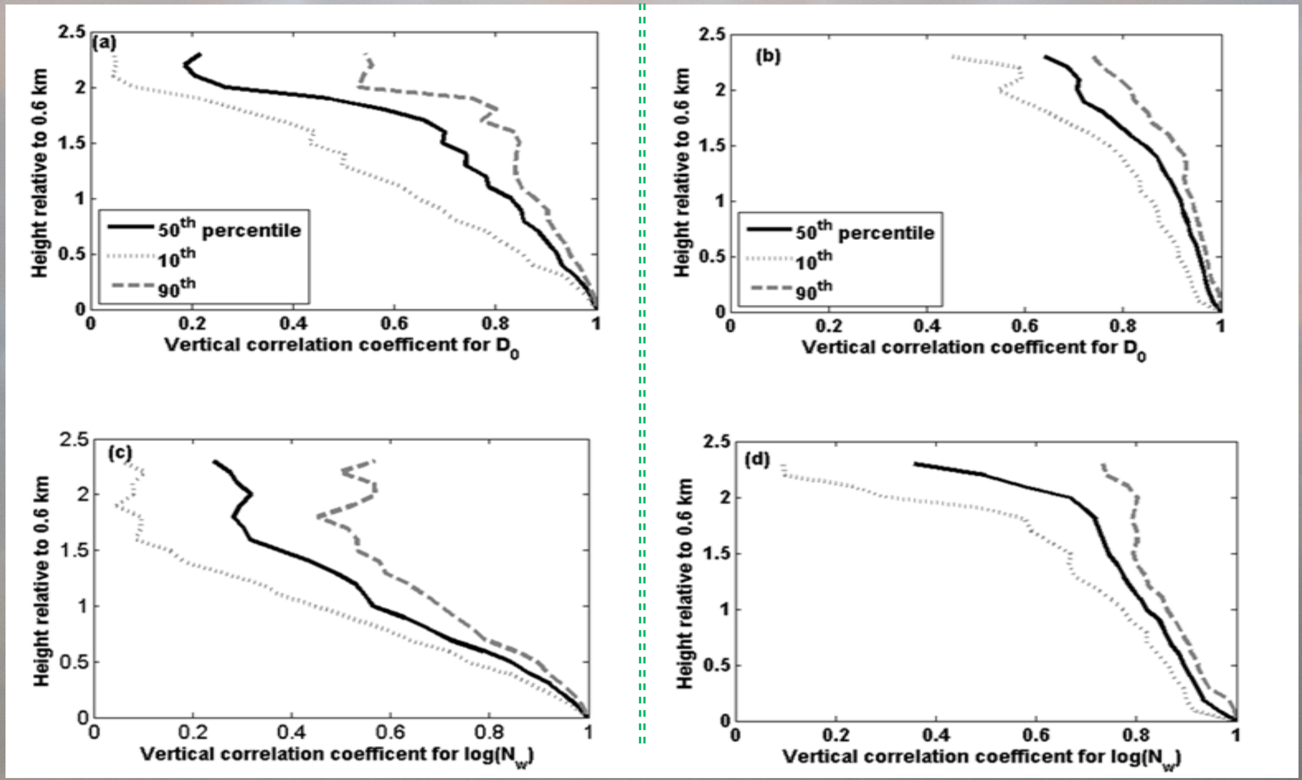
Our Task: *Can we constrain N_w assumptions by developing vertical relationships between PSD and DSD parameters using GV data?*

Early Results: Vertical Correlations of DSD Parameters (M. Thurai)

Vertical correlations of DSD parameters from repeated (~40 s) NPOL-RHI scans taken along SGP-CF azimuth during two MC3E events

April 24 2011 (convective)

May 11 2011 (during stratiform rain period)



- As expected, vertical correlations in both D_0 and N_w decrease more rapidly during convective times compared with stratiform times
- BUT $\text{Log}(N_w)$ decorrelates more rapidly in convection than D_0

Impacts of NUBF on DPR Retrieval Algorithms

Impacts

- NUBF affects measured Z at a radar resolution volume
- NUBF affects attenuation at same resolution volume, plus, reflectivities at subsequent range gates

Background (Theory)

- Toshio Iguchi's NUBF correction theory (2009) is rigorous & elegant
- Assumptions in NUBF theory:
  1. Assumes coefficients in k-Z relationship are constant with range (maybe valid at nadir, but valid off-nadir?)
  2. Critical parameter in NUBF theory is coefficient of variation in k: CV(k) = std(k) / Expected value(k)

How can GV Observations help Evaluate NUBF?

Can GV observations support or improve upon Iguchi's NUBF correction theory?

Some topics discussed in NUBF sub-group:

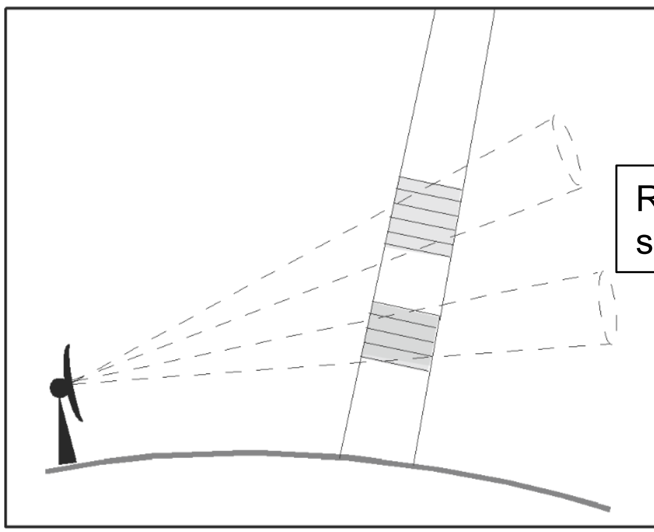
- Quantify sub-grid DPR rain variability using GV radars (network radars)
  - Large datasets to get good statistics of different rain regimes
- 3D structure
  - Horizontal structure
    - Correlation length across multiple FOVs
  - Vertical structure
    - Relationships between horizontal & vertical structures
  - View angle dependence (slant view through vertical structures)
- Analyses need to include DSD parameters to get attenuation estimates at Ku and Ka

VN and MRMS merger for NUBF studies

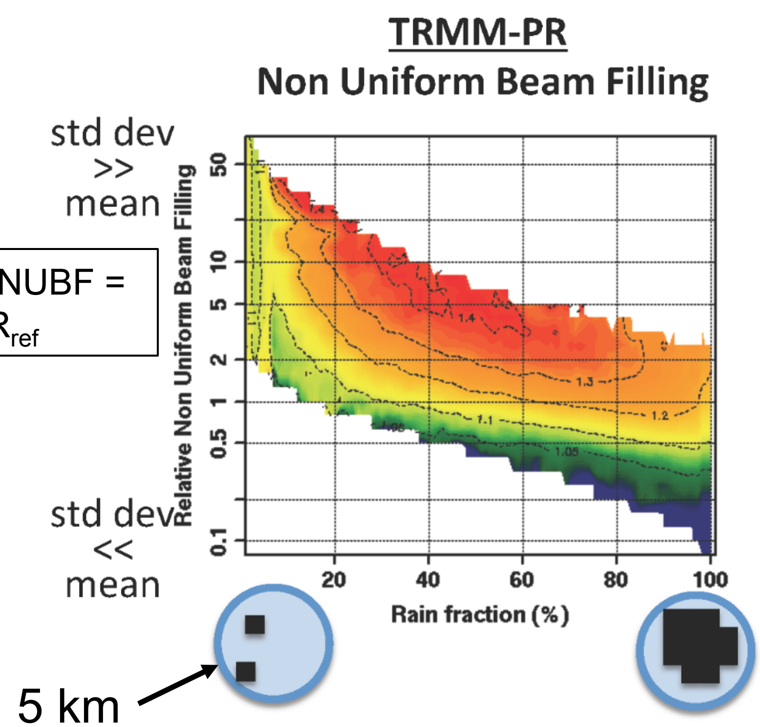
→ VN volume matching dataset (Bob Morris): raw 88D data (QC'd) and GPM Core data for each satellite coincidence

→ MRMS: sub-footprint variability

Large data base
to get statistics across
different rain regimes

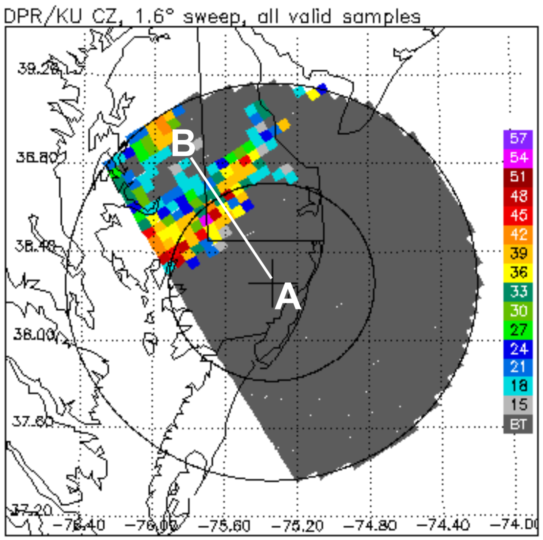


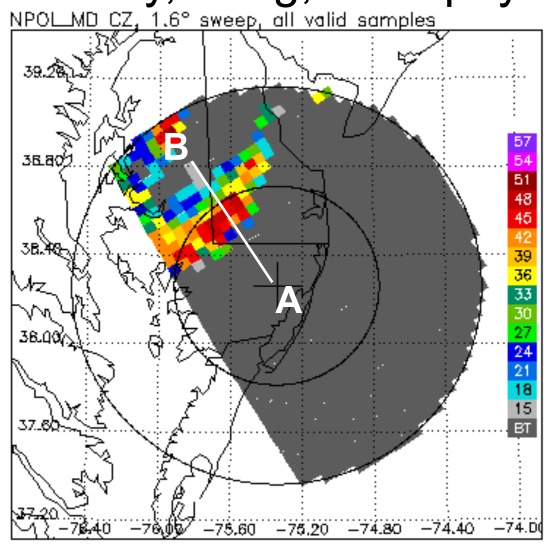
Relative NUBF = std(R) / R_{ref}

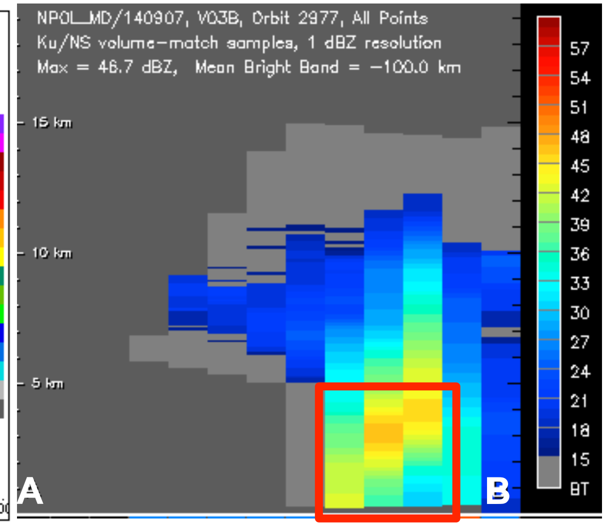


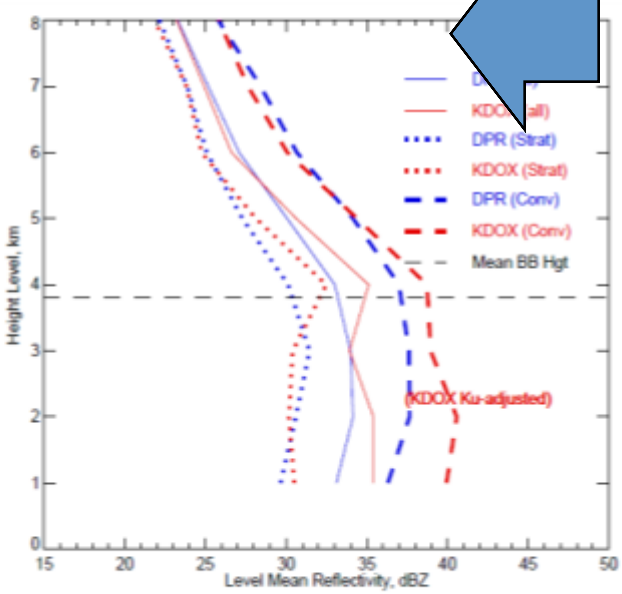
Pierre Kirstetter et al. (QJRMS 2014)

Examine roles of beam geometry, filling, microphysical variability on products



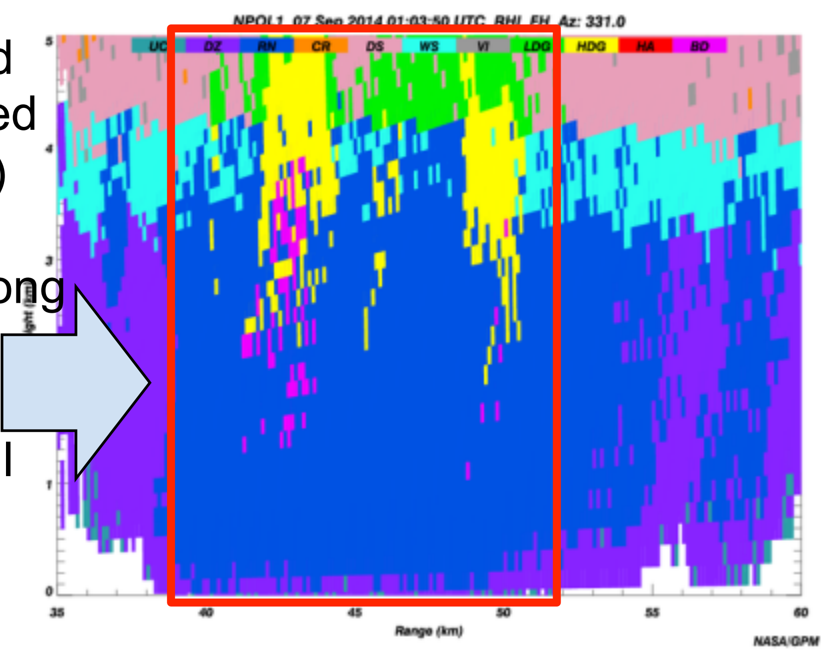






NPOL, KDOX and DPR well- matched in ice @ (7-10km)

Differences in strong convective cells where NPOL reveals that small hail, graupel and large drops exist



NPOL Observations (Wallops Island) from 07-Sept-2014

High resolution data to investigate horizontal & vertical structure

5 x 0.5 km grid boxes

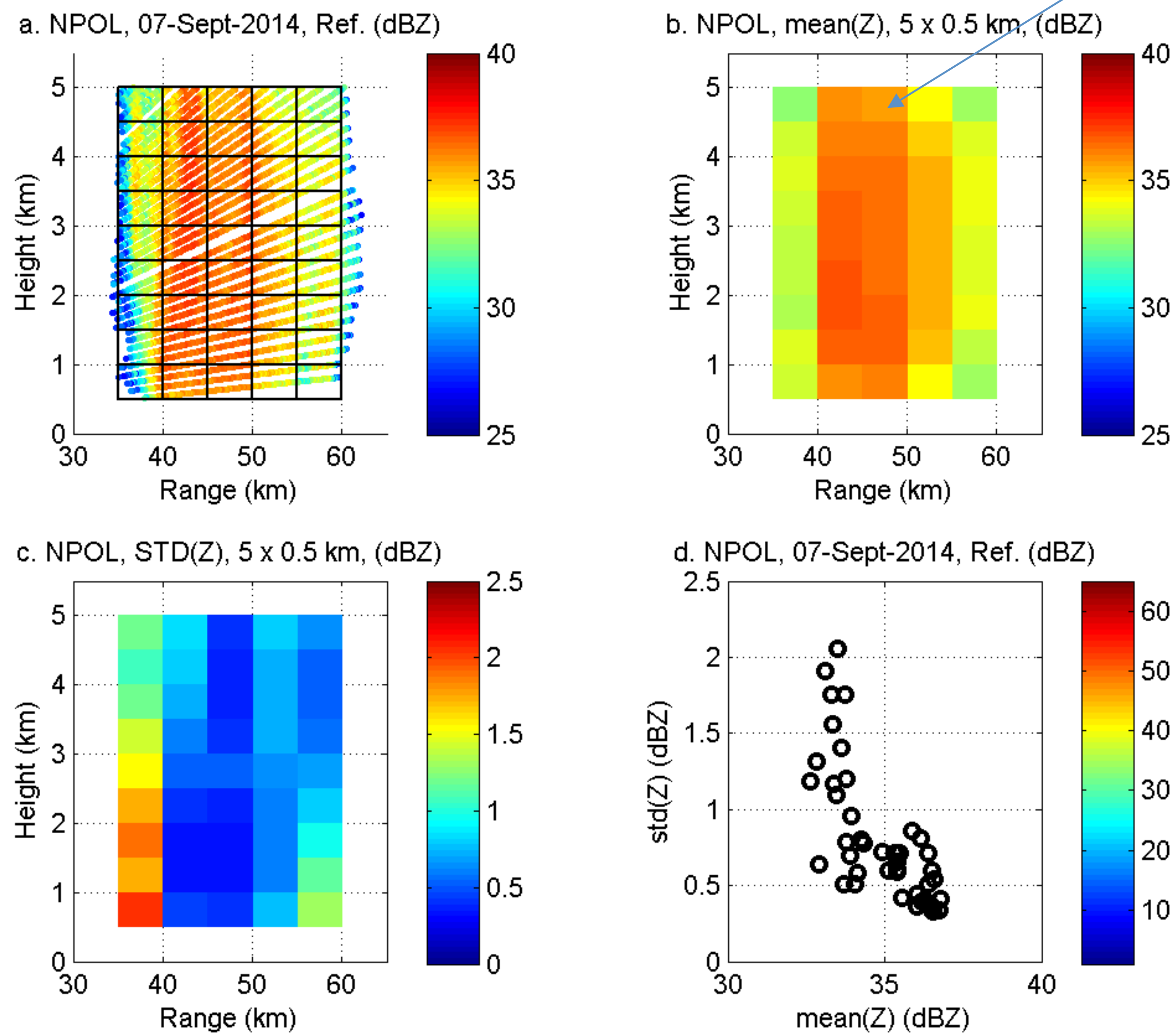
RHI scan

Raw obs.

Mean(Z)

Std(Z)

Std(Z) vs. mean(Z)



We are Adaptive & Collaborative

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New Subgroup: Electromagnetic scattering?

PSD WG Meeting: Cazbar Restaurant, 12noon-1:10 pm

- *Monthly Phone Call: 3rd Thursday, 11 AM Eastern Time*

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